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WOOD ANATOMY OF SOME *FICUS* SPECIES OF MIZORAM, NE INDIA WITH REFERENCE TO THEIR IDENTIFICATION

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ABSTRACT

The present investigation was made on 12 *Ficus* species to evaluate similarities and dissimilarities among species on the basis of anatomical features. The selected *Ficus* species had some similar features like diffuse porous wood, vessels solitary or in radial multiple of 2-3, simple perforation plate, intervessel pits alternate, vessel ray pits similar to intervessel pits in size and shape, banded parenchyma and heterocellular rays. While, some dissimilar characters like presence of both homocellular and heterocellular rays in *F. racemosa* and *F. rigida*, latex ducts in *F. geniculata*, *F. racemosa* and *F. rigida*, axial parenchyma lozenge aliform in *F. hispida* were observed. Rhomboidal crystals were absent in *F. benghalensis, F. geniculata, F. hispida* and *F. racemosa*. In addition to qualitative anatomical features, quantitative anatomical like fibre length, vessel length fibre diameter, fibre wall thickness, ray height and ray width showed significant differences among species. Fibre length was significantly and positively correlated to fibre diameter and vessel length, whereas wood density was significantly and negatively correlated to vessel length and vessel diameter.

KEYWORDS: *Ficus* Sps., Intervessel Pits, Tissue Proportion, LATEX ducts, Crystals

INTRODUCTION

Ficus L., a single genus of tribe Ficeae is widely distributed throughout the world in tropical and sub tropical regions. It is one of the most diversified genera and is distinguished by syconium, an enclosed inflorescence and obligate mutualism with pollinating fig wasps (Clement and Wieblen, 2009). Its habit ranges from shrubs, trees to hemi epiphytes and stranglers. It includes 6 subgenera, 19 sections and 27 subsections on the basis of morphological features and distributional pattern (Berg and Corner, 2005). The genus *Ficus* comprises of 800 species, of which 115 species have been recorded from India. Maximum diversity of *Ficus* with 61 species is known to occur in NE India. It is represented by 43 species in Meghalaya and therefore this state is considered as a hot spot region for this genus (Choudhary *et al.*, 2012).

Anatomical characteristics like cell types, their distribution, number and size play an important role in wood identification and also in determining the characteristics of trees like biomechanical support, storage capacity for water, nutrients and chemical compounds like carbohydrates and lignin (Chave *et al.*, 2009). Also, the suitability of any wood for particular use is determined by its structure and physical properties. The perusal of literature has revealed sparse data on wood anatomy of *Ficus* sps. Noorman *et al.* (1984) studied the wood structure in large number of Neotropical and African *Ficus* species. Damyanti and Rulliaty (2010) examined the anatomical properties and fibre quality of *F. nervosa* Heyne.

Recently Adeniyi *et al.* (2013) made comparative study on wood anatomy of *F. ingens, F. exasperate, F. vallischoudae, F. vogelina, F. muccuso, F. elastica* and *F. indica* from Nigeria. Sixteen species of *Ficus* are reported from Mizoram (Sawmliana, 2003) and the wood anatomy of 12 species is carried out with the main objectives to determine the interspecific similarities and dissimilarities by means of wood anatomical features. An attempt has also been made to prepare identification key and dendrogram on the basis of these features.

MATERIAL AND METHODS

Wood samples of different *Ficus* species were collected from forests of Mizoram as listed in Table 1. The selected sites are geographically situated between $21^0 58´$-$24^0 35´$N latitude and $92^0 15´$- $93^0 29´$E longitude Figure 1. For each species, three mature trees of uniform diameter were selected and wood samples of $5cm^3$ were taken at breast height. These samples were further cut into $2cm^3$ size and fixed in FAA for 24-48 hours, after which they were preserved in 50% alcohol. Cross sections, tangential longitudinal sections and radial longitudinal sections were cut with the help of sliding wood microtome. They were stained as per standard procedure and permanent slides were prepared to study the anatomical features. The other parameters like vessel diameter, vessel frequency, fibre diameter, fibre wall thickness and tissue proportion were studied on cross section while ray height and ray width were measured on tangential longitudinal sections.

Small slivers taken from radial side of each block of *Ficus* species were macerated with Franklin's solution and temporary slides were made by using 50% glycerol for fibre length and vessel length measurements. A random sample of 30 fibres and 30 vessels were selected for measurement of their length. From each sample, 30 counts were taken for vessel diameter, fibre diameter, fibre wall thickness, ray height and ray width while 10 fields were selected for vessel frequency and tissue proportion. The anatomical features were studied with standard procedures (IAWA Committee, 1989). Water displacement method was used for wood density determination. The collected data were analysed statistically by Microsoft Excel 7 and SPSS 16.

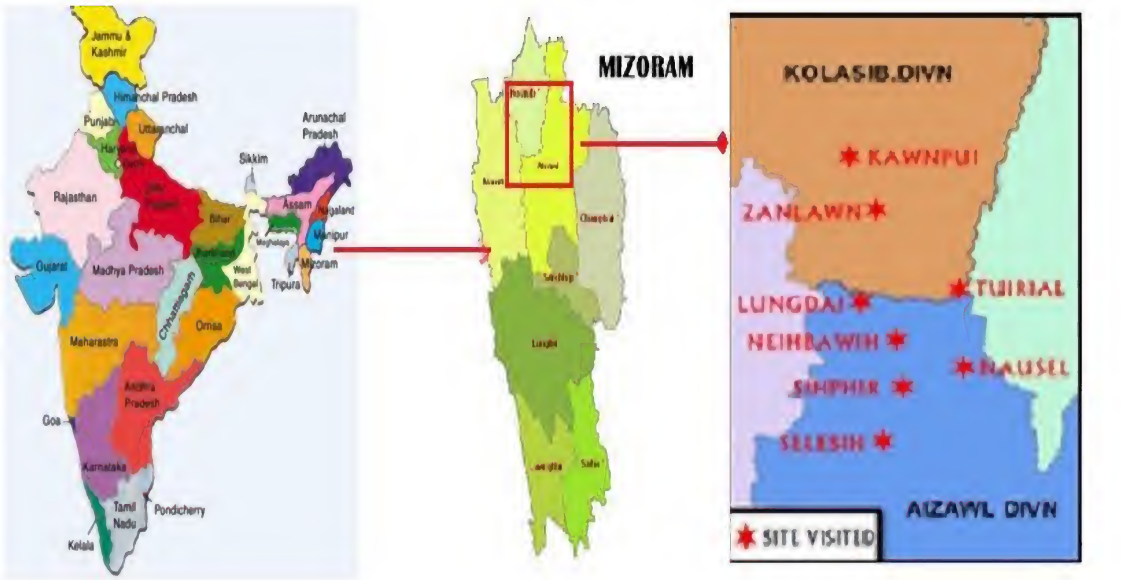

Figure 1: Location Map of Study Area

Table 1: List of Selected *Ficus* Species

Sl No.	Name of Species	Mizo Name	Locality
1	*Ficus altissima*	Pual bung	Tuirial
2	*Ficus auriculata*	Thei-bal	Kawnpui/Zanlawn
3	*Ficus benghalensis*	Bung	Neihbawih
4	*Ficus benjamina*	Za-man-hmawng	Selesih
5	*Ficus elastica*	Thelret	Thelret
6	*Ficus geniculata*	Ri-hnim	Sihphir
7	*Ficus hirta*	Sazutheipui	Nausel/ Neihbawih/ Lungdai
8	*Ficus hispida*	Theithawt	Nausel
9	*Ficus prostrata*	Theitit	Zanlawn/Nausel
10	*Ficus racemosa*	Theichek	Nausel
11	*Ficus religiosa*	Hmawng	Lungdai/Selesih
12	*Ficus rigida*	Thuah-riat	Sihphir/Neihbawih

RESULTS AND DISCUSSIONS

The selected *Ficus* species did not show distinct sapwood and heartwood. The colour of wood was white or grey which turned yellow on exposure. Wood anatomical characters of *Ficus* species were summarized in Table 2-4. All species had diffuse porous woods with indistinct growth rings. Vessels were circular or oval in outline and solitary or in radial multiple of 2-4. Vessel length, vessel diameter and vessel frequency varied from 257.25±35.06 µm (*F. geniculata*) to 411.66±80.41 µm (*F. altissima*), 123.49±17.09 µm (*F. hirta*) to 230±40.89 µm (*F. altissima*) and 2 vessels per mm^2 (*F. benghalensis*, *F. religiosa, F. rigida* and *F. benjamina*) to 9 vessels per mm^2 (*F. auriculata*). Simple perforation plate, intervessel pits alternate and vessel ray pits similar to intervessel pits in size and shape were present ("Figure 2"). Vessel percentage was recorded as 17 % (*F. racemosa*) to 28% (*F. geniculata* and *F. hirta*) "Table 4". Fibres constituting the ground tissue were square or polygonal in outline, thin to thick walled. The range of fibre length, fibre diameter and fibre wall thickness were recorded as 958.65±109.39 µm (*F. geniculata*) to 1800.50±201.20 µm (*F. altissima*); 231.88±36.55 µm (*F. hispida*) to 311.16±54.75 µm (*F. elastica*) and 4.06±1.07 µm (*F. rigida*) to 8.91±2.03 µm (*F. prostrata*) respectively. Fibre percentage varied from 22% (*F. hirta*) to 36% (*F. rigida*) Table 4. Septate Fibres present occasionally except *F. altissima*. Laticifers in the form of dark streaks were interspersed among fibres in *F. altissima*, *F. auriculata*, *F. elastica*, *F. hirta*, *F. religiosa* and *F. rigida* (Figure 4).

Rays were uniseriate, biseriate and multiseriate in all selected species except *F. benjamina* in which only multiseriate rays were recorded (Figure 3). Ray height and ray width ("Table 3") varied from 426.94±78.52 µm (*F. geniculata*) to 726.62±160.75 µm (*F. auriculata*) and 4 seriate (*F. altissima*, *F. elastica* and *F. hispida*) to 10 seriate (*F. auriculata*). Rays were mostly heterocellular and composed of procumbent cells and square/upright cells. Homocellular rays consisting of either procumbent cells or square cells were recorded in *F. benghalensis*, *F. racemosa* and *F. rigida* ("Figure 4"). Rays per mm. varied from 2 (*F. racemosa*) to 8 (*F. benjamina*). Rays percentage varied from 17% (*F. rigida*) to 31% (*F. altissima*) Table 4. Rhomboidal crystals were observed in rays of some species namely *F. auriculata*, *F. geniculata*, *F. hirta* and *F. rigida*. Latex ducts were recorded in *F. geniculata*, *F. racemosa* and *F. rigida* and sheath cells were recorded in *F. hirta* and *F. racemosa* (Figure 3) Banded parenchyma was present in all species except *F. hispida* in which lozenge aliform and irregular bands were present. In addition, vasicentric parenchyma was present in *F. benghalensis, F. benjamina* and *F. hirta*. Bands were more than 3 cells wide (Figure 2). Parenchyma strands were 3-8

celled. Crystals and yellow brownish deposits were recorded in most of the species (Figure 3 & 4). Parenchyma percentage varied from 21% (*F. geniculata*) to 32% (*F. racemosa*).

The present study revealed that selected *Ficus* species were consistent and uniform in many anatomical characters like diffuse porous wood, solitary vessel, simple perforation plate, intervessel pits alternate, vessel ray pitting and banded parenchyma. The combination of these features can be regarded as characteristics of genus *Ficus* as they are present in all selected species. However, the selected species differ in their wood characters like presence of homocellular and heterocellular rays and latex ducts in *F. racemosa* and *F. rigida*, absence of septate fibres in *F. altissima*, presence of sheath cells in rays of *F. hirta and F. racemosa*, presence of lozenge aliform parenchyma in *F. hispida* and vasicentric parenchyma in *F. benghalensis, F. benjamina* and *F. hirta*. Hence, these features can be considered for identification of these species.

ANOVA carried out for quantitative wood characters like vessel length, vessel diameter, fibre length, fibre diameter, fibre wall thickness, ray height and ray width showed statistically significant differences among species (Table 5).

The result presented in (Table 6) showed Pearson's correlation among different wood element parameters. Fibre length showed positive and significant correlation with vessel length (0.832^{*}) while wood density exhibited negative and significant correlation with vessel length (-0.613^{*}) and vessel diameter (-0.604^{*}). Fibre diameter showed positive and significant correlation with fibre wall thickness (0.583^{*}). The correlation among other parameters was too weak to be significant. It indicated that quantitative anatomical characters influence each other to some extent. Hence, the *Ficus* species could be differentiated on the basis of quantitative anatomical characters. The present study confirms the findings of other workers (Pande *et al.*, 2005; Sharma *et al.*, 2011 a, b; Singh *et al.,* 2013).

Hierarchial cluster analysis was done to see close affinity among *Ficus* species on the basis of anatomical features like fibre length, fibre diameter, fibre wall thickness, vessel length, vessel diameter, ray height, ray width and wood density. The dendrogram presented in (Figure 5) showed 4 clusters at 25 inter-cluster distance. In Ist cluster, *F. altissima* was separated at 8 inter-cluster distance. IInd cluster having *F. elastica* and *F. religiosa* was clustered with Ist cluster at 13 inter-cluster distance. In IIIrd cluster having *F. auriculata* was separated at 22 inter-cluster distance while only *F. geniculata* formed 4^{th} cluster at 25 inter-cluster distance. A survey of literature reveals that *Ficus* species are divided into six subgenera namely Urostigma, Sycomorous, Ficus, Sycidium, Synoecia and Pharmacosycea (Berg and Corner, 2005; Choudhary *et al.*, 2012). On the other hand, the molecular studies conducted on *Ficus* species by nuclear markers (ITS, ETS and G3pdh) and rbCL do not support the classification of Ficus into subgenera as subgenus Urostigma is closely related to subgenera Ficus and Sycomorus (Herre *et al.,* 1996; Ronsted *et al.*, 2008 a,b).In the present study, species of different subgenera are present together in the same cluster showing close association among different subgenera and therefore corroborates the findings of these workers.

A key for identification of *Ficus* species is given below.

1. Septate fibres absent --------*Ficus altissima*

Septate fibres present --------2

2. Fibre length less than 1000µm --------*F. geniculata*

Fibre length greater than 1000µm --------3

3. Vessel density 2-3 per mm^2 --------4

Vessel density 4-9 per mm^2 --------6

4. Fibre length more than 1600µm --------*F. benghalensis*

Fibre length lessthan 1500µm --------5

5. Crystals absent in parenchyma --------*F. elastica*

Crystals present in parenchyma --------*F. religiosa*

6. Rays 6-15 cells wide --------*F. auriculata*

Rays 3-12 cells wide --------7

7. Sheath cells present --------8

Sheath cells present --------9

8. Axial parenchyma banded --------*F. prostrata*

Both banded and lozenge aliform parenchyma present --------*F. hirta*

9. Regular bands of banded parenchyma present --------10

Lozenge aliform and irregular bands of parenchyma --------*F. hispida*

10. Latex ducts present in rays --------11

Latex ducts absent in rays --------*F. benjamina*

11. Crystals present in rays --------*F. rigida*

Crystals absent in rays --------*F. racemosa*

CONCLUSIONS

All the selected *Ficus* species had similar features like diffuse porous wood, vessels solitary or in radial multiple of 2-3, simple perforation plate, intervessel pits alternate, vessel ray pits similar to intervessel pits in size & shape, banded parenchyma and heterocellular rays. Septate fibres were present in all species except *F. altissima*. The dissimilar features were presence of latex ducts in *F. geniculata, F. racemosa, F. rigida*, both homocellular and heterocellular rays in *F. racemosa* and *F. rigida*, lozenge aliform in *F. hispida*, absence of crystals in *F. benghalensis*, *F. geniculata, F. hispida* and *F. racemosa*. Quantitative anatomical characters namely fibre length, fibre diameter, fibre wall thickness, vessel length, vessel diameter, ray height, ray width and wood density exhibited statistically significant differences among species. In Pearson's correlation matrix, fibre length showed positive and significant correlation with fibre diameter and vessel length while wood density was negatively and significantly correlated to vessel length and vessel diameter.

The identification key was prepared on the basis of anatomical characters like fibre length, vessel diameter, ray composition, type of parenchyma, presence and absence of latex ducts, sheath cells and crystals. Hierarchial cluster analysis showed formation of four clusters and the species belonging to different subgenera of *Ficus* species are clustered together in same cluster.

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APPENDICES

Table 2: Microscopic Features of Vessels and Fibres of Selected *Ficus* Species

Name	Vessel Length (µm) (Mean±SD)	Vessel Diameter(µm) Mean±SD	Vessel Frequency	Fibre Length (µm) Mean±SD	Fibre Diameter (µm) Mean±SD	Fibre Wall Thickness (µm) Mean±SD
F. altisimma	256.40 - 529.89 411.66± 80.41	158.04 - 305.65 230.00±40.89	3 - 4	1461.48 - 2239.23 1800.50± 201.20	219.25 - 368.34 289.76±37.03	3.03 - 7.80 5.51± 1.24
F. auriculata	264.95 - 555.53	118.09 - 191.03	4 – 9	1145.25 - 1880.27	175.40 - 350.80	3.03 - 8.67
	366.08± 66.75	155.47± 18.19		1477.72±166.55	285.20± 46.75	5.81±1.48
F. benghalensis	264.95 - 521.35	133.72 - 255.29	2 – 3	1376.01 - 2059.75	184.17 - 342.03	3.03 - 6.50
	385.74± 75.68	185.55± 35.18		1638.11±167.45	253.63± 42.85	4.97± 1.04
F. benjamina	205.12 - 427.33	154.56 - 265.71	2 – 5	1119.61 - 1991.37	175.40 - 315.72	3.03 - 6.93
	303.98±55.13	210.00± 29.05		1485.13± 202.68	247.66± 35.76	5.22±1.25
F. elastica	205.12 - 546.98	168.45 - 270.92	2 – 4	1145.26 - 1837.52	219.25 - 412.19	4.3 - 7.8
	370.35± 98.12	214.35± 26.29		1465.19± 178.474	311.16± 54.75	6.198± 1.060
F. geniculata	153.84 - 350.41	121.57 - 232.71	2 – 3	717.92 - 1358.92	228.02 - 412.19	3.90 - 8.67
	257.25± 35.06	175.89±17.34		958.65± 109.39	296.08± 29.94	6.15± 0.89
F. hirta	230.76 - 470.07	93.90 - 171.65	3 - 7	1119.61 - 1914.45	210.48 - 342.03	3.47 - 8.67
	340.16± 63.39	123.49± 17.09		1530.99± 182.63	274.68± 38.68	5.84± 1.35
F. hispida	230.76 - 478.61	140.67 - 247.85	3 - 5	974.32 - 2017.01	157.86 - 289.41	3.03 - 7.80
	348.70± 66.06	194.61±28.72		1459.77±252.18	231.88± 36.55	5.18± 1.24
F. prostrata	205.12 - 393.146	154.56 - 265.22	3 – 7	1034.14 - 1880.26	219.25 - 377.11	5.6 - 13
	277.76± 52.561	191.456 ± 23.566		1407.35± 204.45	294.32± 42.23	8.91 ± 2.03
F. racemosa	264.94 - 512.8	142.40 - 274.39	2 – 6	1085.4 - 2051.2	192.94 - 343.77	3.03 - 7.36
	373.77± 60.618	140.45± 31.54		1568.8± 226.20	276.78± 50.02	5± 1.12
F. religiosa	239.30 - 478.61	135.46 - 222.29	2 – 4	1820.44 - 1059.78	149.09 - 368.34	2.6 - 6.9
	343.096± 61.120	181.51± 22.57		1406.78± 190.80	262.4± 60.91	4.524± 1.259
F. rigida	273.49 - 470.07	135.46 - 243.13	2- 5	1187.99 - 1794.80	156.30 - 281.34	2.60 - 6.07
	357.82± 48.20	190.13±25.99		1503.07±162.66	230.49± 30.72	4.06± 1.07

Table 3: Microscopic Features of Rays of Selected *Ficus* Species

Species	Ray Height (µm) Mean±SD	Seriation	Rays/mm	Crystals	Latex Duct	Sheath Cells
F. altisimma	277.87 - 1035.05 606.58 ± 242.42	2-7	5-7	Absent	Absent	Absent
F. auriculata	371.65 - 1066.31 726.62 ± 160.75	6-15	3-5	Present	Absent	Absent
F. benghalensis	243.13 - 871.81 586.02±175.55	3-8	3-4	Absent	Absent	Absent
F. benjamina	263.97 - 798.87 482.10 ± 143.25	3-7	6-8	Absent	Absent	Absent
F. elastica	131.99 - 757.187 489.74 ± 136.44	3-7	3-4	Absent	Absent	Absent
F. geniculata	197.98 - 677.30 426.94 ± 78.52	3-7	5-7	Present	Present	Absent

Table 3: Contd.,

F. hirta	270.92-1069.79 551.70 ± 207.16	3-9	4-5	Present	Absent	Present
F. hispida	253.55 - 812.76 509.47 ± 141.83	3-6	4-5	Absent	Absent	Absent
F. prostrata	340.386 - 958.64 643.26 ± 157.13	3-12	4-6	Present	Absent	Absent
F. racemosa	312.6-996.84 646.73 ± 178.12	5-10	2-5	Absent	Present	Present
F. religiosa	215.34 - 864.86 480.15 ± 194.45	3-7	5-7	Absent	Absent	Absent
F. rigida	309.13 - 878.75 543.09±137.74	3-9	4-5	Present	Present	Absent

Table 4: Tissue Proportion Measurement of Selected *Ficus Species*

Species	Fibre (%)	Vessel (%)	Ray (%)	Parenchyma (%)
F. altisimma	26	21	31	22
F. auriculata	32	22	22	24
F. benjamina	26	19	29	26
F. benghalensis	30	19	27	24
F. elastica	34	21	23	22
F. geniculata	24	28	27	21
F. hirta	22	28	24	26
F. hispida	24	22	27	27
F. prostrata	28	24	25	23
F. racemosa	27	17	24	32
F. religiosa	24	19	27	30
F. rigida	36	23	17	24

Table 5: Analysis of Variance for Selected Parameters among Different *Ficus Species*

Dependent Variables	Sum of Squares	Df	MSS	F Value	P Value
Fibre length	3794180E+07	11	3449255E+06	81.70	0.00*
Fibre diameter	454414	11	41310	19.10	0.00*
Fibre lumen diameter	5705.6	11	518.7	29.41	0.00*
Fibre wall thickness	1210.91	11	110.08	50.91	0.00*
Vessel length	1991079	11	181007	34.48	0.00*
Vessel diameter	338566	11	30779	35.23	0.00*
Ray height	6224609	11	565874	17.99	0.00*
Ray width	305751	11	27796	97.12	0.00*
Wood density	0.65840	11	0.05985	19.73	0.00*

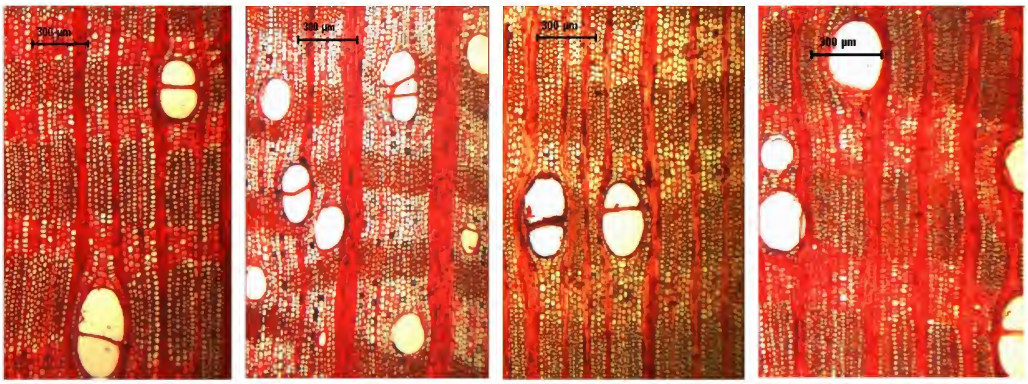
Table 6: Pearson Correlation among Parameters of Different Wood Elements

		FL	FD	FWT	VL	VD	RH	RW	WD
FL	Pearson Correlation	1	-.184	-.228	.832**	.047	.521	-.005	-.371
	Sig. (2-tailed)		.566	.476	.001	.884	.082	.988	.235
FD	Pearson Correlation	-.184	1	.583*	-.076	.267	.149	.253	.080
	Sig. (2-tailed)	.566		.047	.813	.401	.643	.428	.805
FWT	Pearson Correlation	-.228	.583*	1	-.482	-.163	.269	.409	.435
	Sig. (2-tailed)	.476	.047		.113	.613	.397	.186	.157

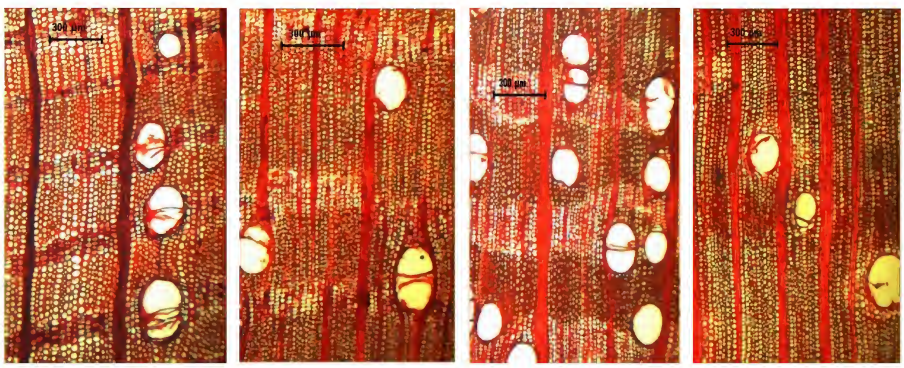
Table 6: Contd.,

VL	Pearson Correlation	.832**	-.076	-.482	1	.209	.413	-.086	-.613*
	Sig. (2-tailed)	.001	.813	.113		.515	.182	.792	.034
VD	Pearson Correlation	.047	.267	-.163	.209	1	-.423	-.445	-.604*
	Sig. (2-tailed)	.884	.401	.613	.515		.170	.147	.038
RH	Pearson Correlation	.521	.149	.269	.413	-.423	1	.804**	.044
	Sig. (2-tailed)	.082	.643	.397	.182	.170		.002	.893
RW	Pearson Correlation	-.005	.253	.409	-.086	-.445	.804**	1	.318
	Sig. (2-tailed)	.988	.428	.186	.792	.147	.002		.314
WD	Pearson Correlation	-.371	.080	.435	-.613*	-.604*	.044	.318	1
	Sig. (2-tailed)	.235	.805	.157	.034	.038	.893	.314	
**. Correlation is significant at the 0.01 level (2-tailed).									
*. Correlation is significant at the 0.05 level (2-tailed).									

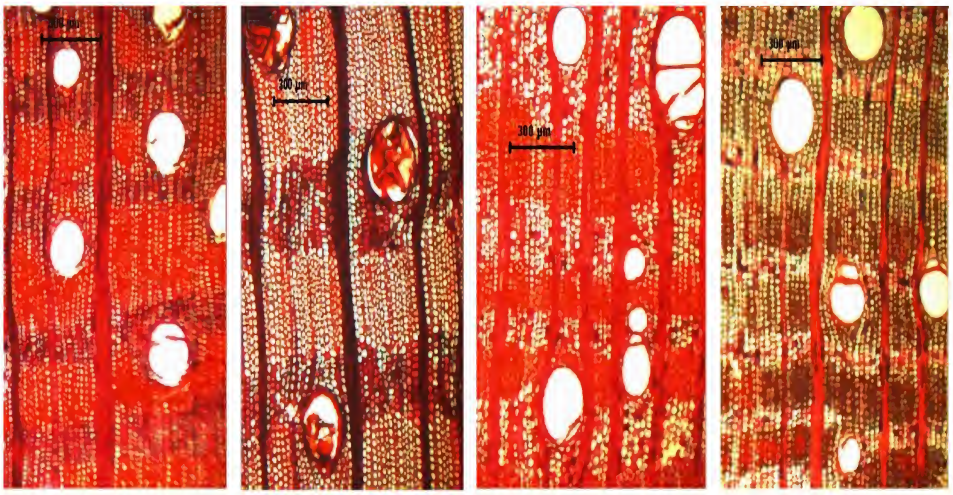
FL - Fibre Length, FD- Fibre Diameter, FWT- Fibre double wall Thickness
VL - Vessel Length, VD-Vessel diameter RH- Ray height
RW- Ray Width WD-Wood density



A. ***Ficus altisimma*** **B.** ***Ficus auriculata*** **C.** ***Ficus benghalensis*** **D.** ***Ficus benjamina***

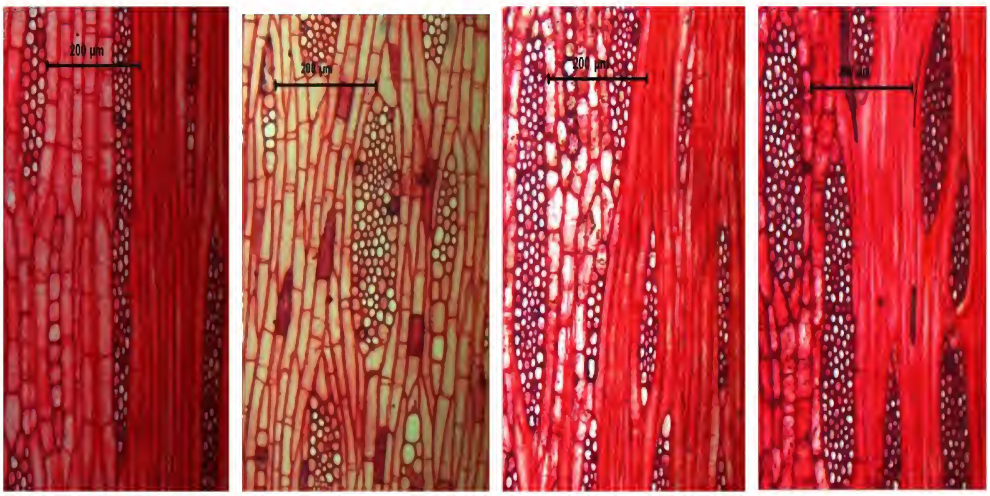


E. ***Ficus elastic*** **F.** ***Ficus geniculata*** **G.** ***Ficus hirta*** **H.** ***Ficus hispida***

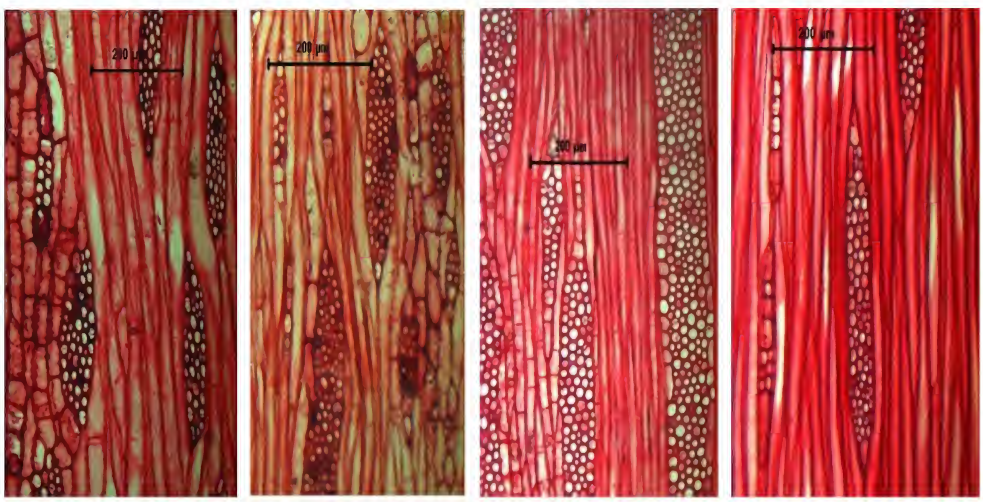


I. *Ficus prostrate* J. *Ficus racemosa* K. *Ficus religiosa* L. *Ficus rigida*

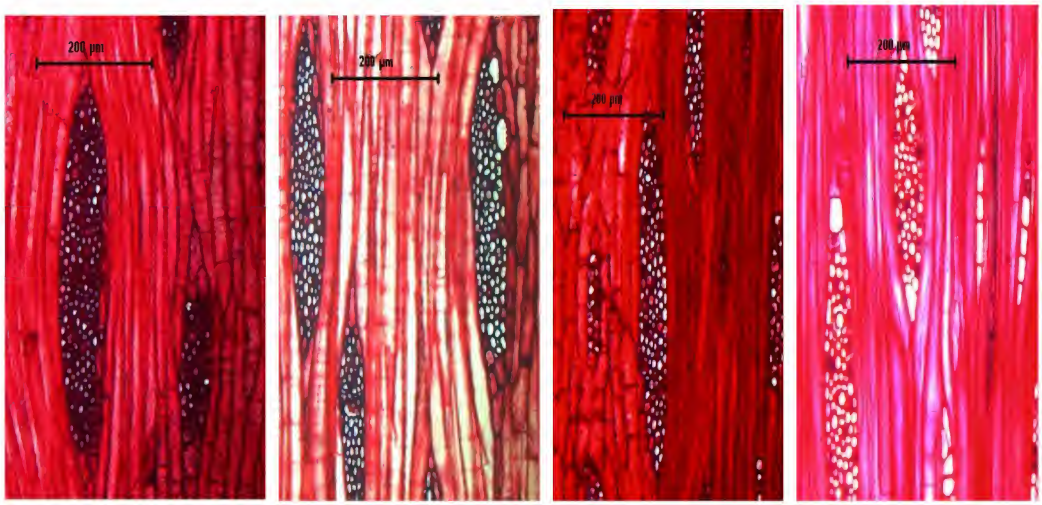
Figure 2 A-L: Cross Sections: Growth Rings Indistinct; Wood Diffuse Porous; Vessels Mostly Solitary and in Radial Multiple of 2 – 3 (Except I and J); Parenchyma. Banded (A to F, I to L), Vasicentric and Lozenge Aliform (G), Lozenge Aliform, Confluent to Irregular Bands (H); Tyloses Present (J)



A. *Ficus altisimma* B . *Ficus auriculata* C. *Ficus benghalensis* D. *Ficus benjamina*

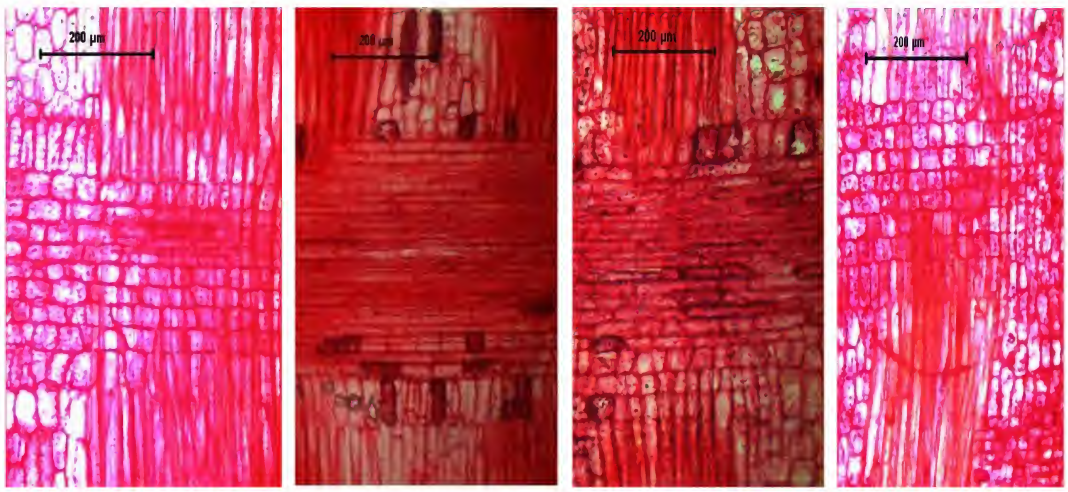


E. *Ficus elastic* F. *Ficus geniculata* G. *Ficus hirta* H. *Ficus hispida*

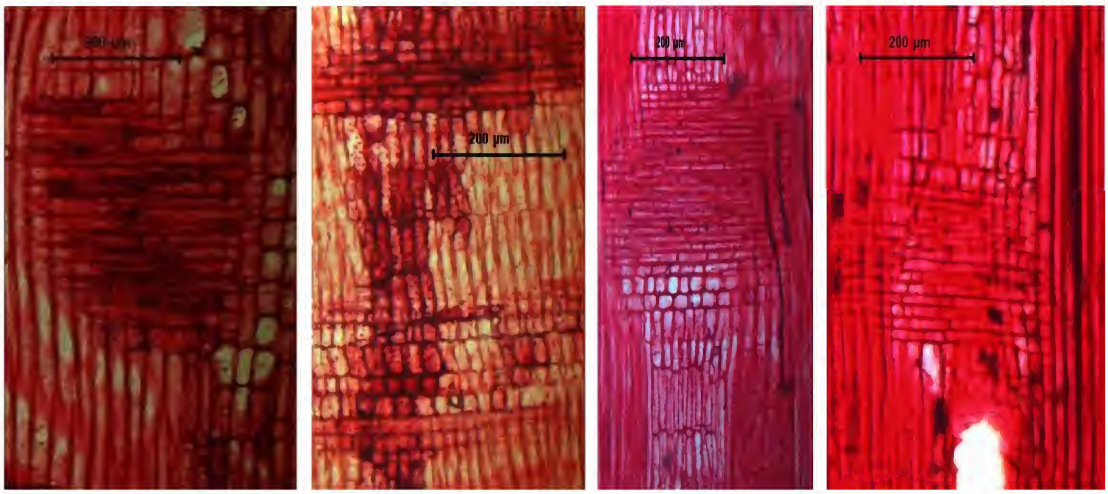


I. *Ficus prostrate* J. *Ficus racemosa* K. *Ficus religiosa* L . *Ficus rigida*

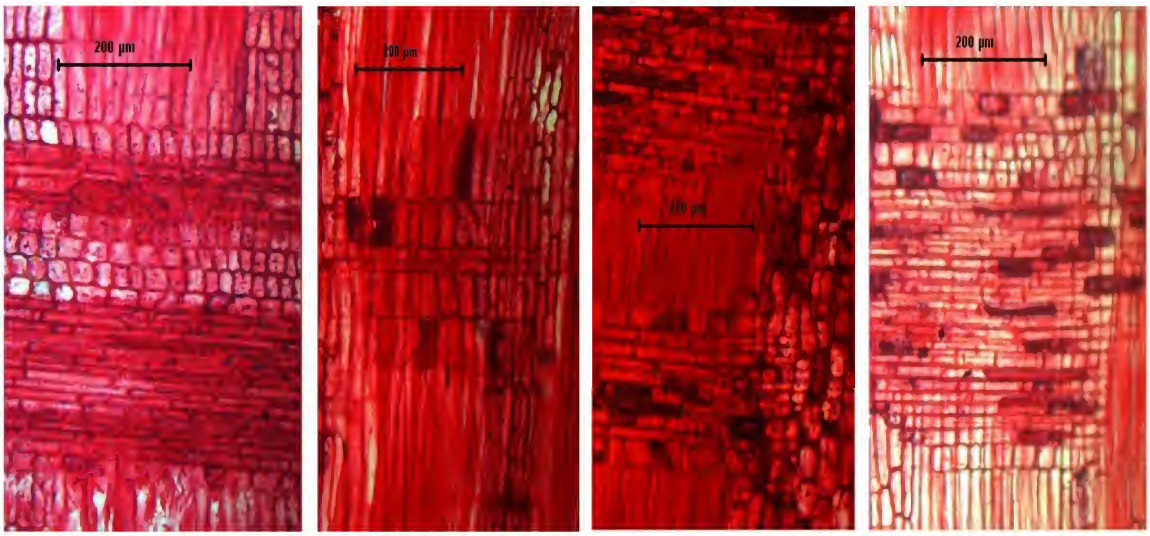
Figure 3 A-L: Tangential Longitudinal Sections: Rays Mostly Multiseriate, Uniseriate or Partly Biseriate in (B, C, E, F, H & K); Longitudinal Black Streaks among Fibres (D & L); Latex Ducts Present in Rays (F & L); Septate Fibres Present (G & L); Sheath Cells Present (G & J)



A. *Ficus altisimma* B. *Ficus auriculata* C. *Ficus benghalensis* D. *Ficus benjamina*



E. *Ficus elastic* F. *Ficus geniculata* G. *Ficus hirta* H. *Ficus hispida*



I. *Ficus prostrate* J. *Ficus racemosa* K. *Ficus religiosa* L. *Ficus rigida*

Figure 4 A-L: Radial Longitudinal Sections: Rays Mostly Heterocellular Consisting of Procumbent and Upright/Square Cells (A – L except D); Homocelluar Ray Consisting of Square Cells (D); Black Streaks among Fibres (G & H); Crystals Present (B, C, F & G)

Dendrogram using Average Linkage (Between Groups)

Rescaled Distance Cluster Combine

```
C A S E  0         5        10        15        20        25
Label    Num +---------+---------+---------+---------+---------+
F.beng     4 -+-+       |         |         |         |
F.hisp     8 -+ |       |         |         |         |
F.benj     3 -+ |       |         |         |         |
F.rigd    12 -+-+       |         |         |         |
F.hirt     7 -+         |         |         |         |
F. alti    1 -----------+         |         |         |
F.race    10 -----+               |         |         |
F.elas     5 -----+---------------+         |         |
F.reli    11 -----+                         |         |
F. aurc    2 -----+---------------+---------+         |
F.pros     9 -----+               |                   |
F.geni     6 -----+---------------+-------------------+
```

Figure 5: H I E R A R C H I C A L C L U S T E R A N A L Y S I S